Search for a low mass SM Higgs Boson at the Tevatron

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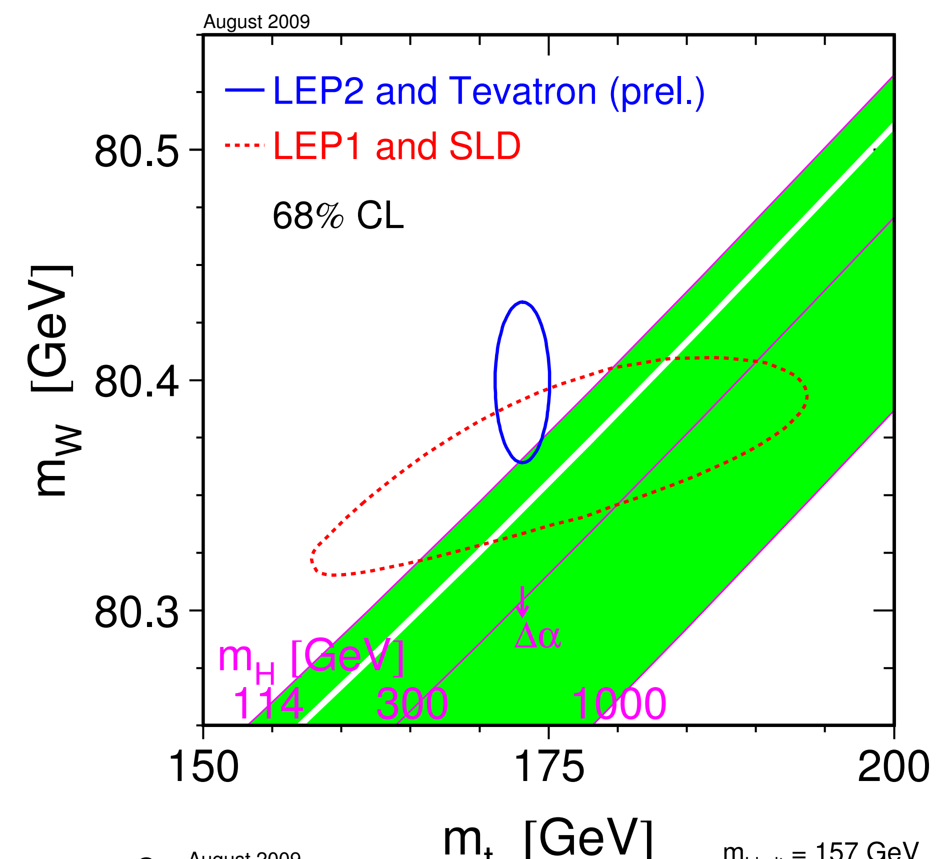
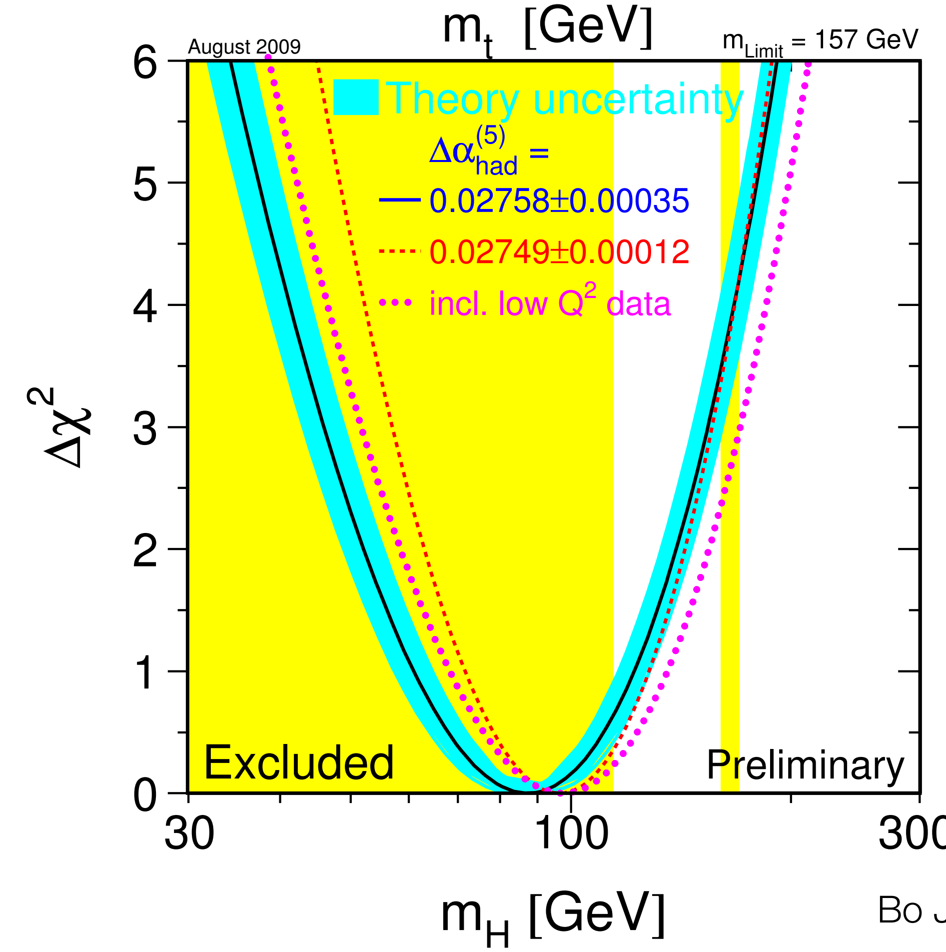
What do we know?

- Something is accountable for EWSB
  - SM allows for Higgs mechanism
  - Manifests a heavy spin-0 boson
- SM predicts most properties and decay channels of Higgs
  - but **not** its mass
- Experimental evidence so far:
  - Direct searches at LEP exclude m_H<114 GeV/c^2
  - Direct searches at Tevatron beginning to exclude around m_H=160 GeV/c^2
  - Indirect constraints from precision measurements (m_W and m_t) prefer low mass Higgs: m_H<157 GeV/c^2 (186 GeV when including LEP limit)

From LEPEWWG

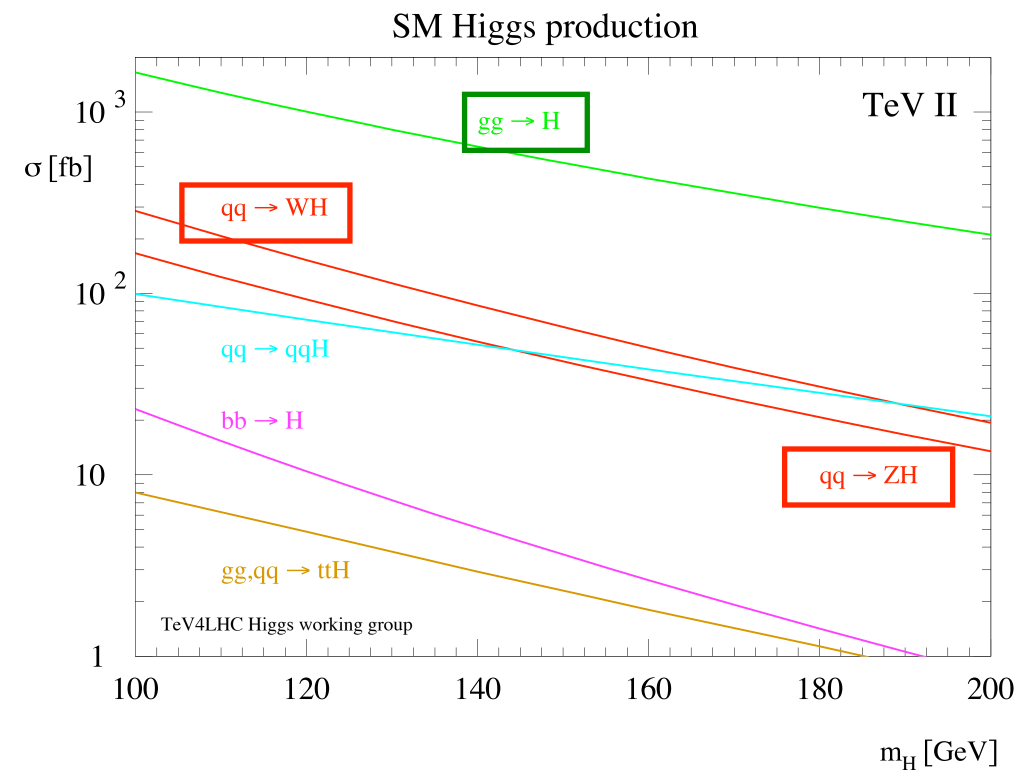


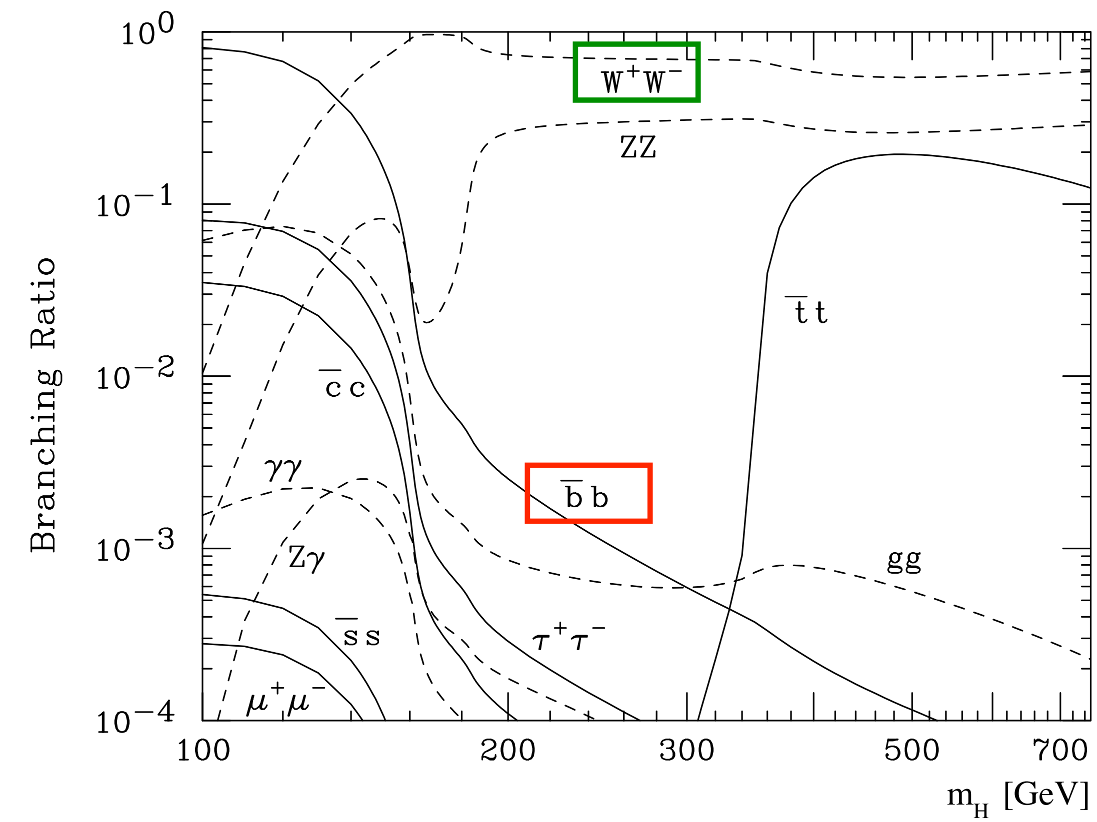


What do we look for?

Separate according to decays:

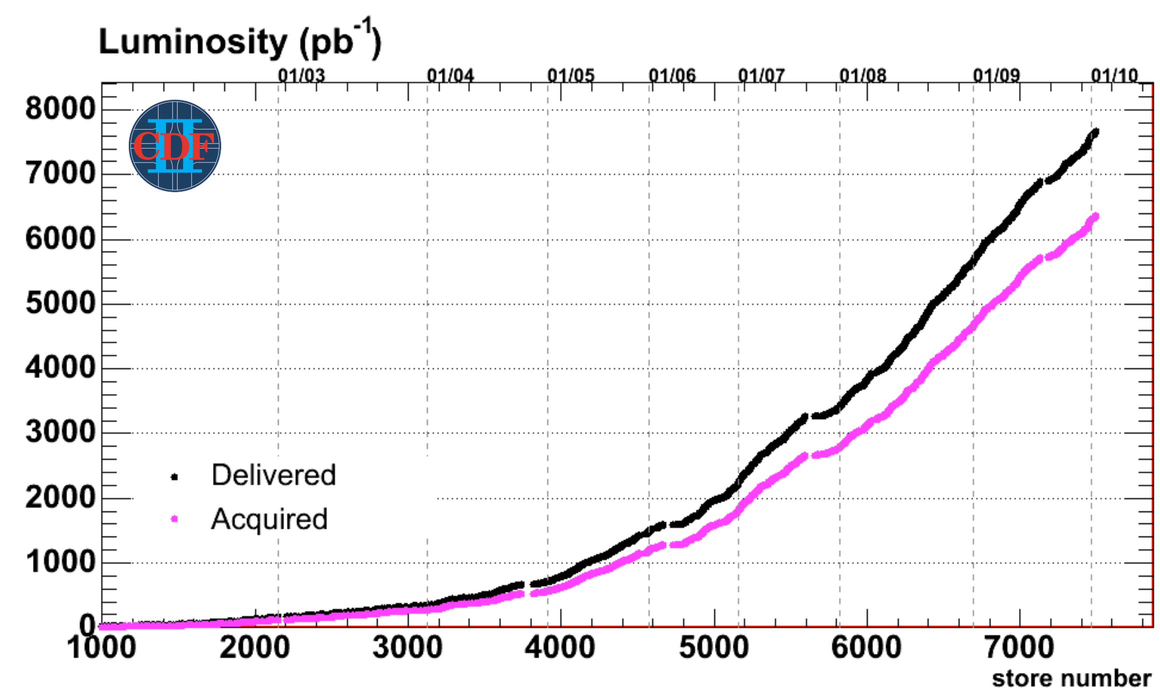
- Low mass [m_H<135 GeV]
  - Decays dominated by $H \to b\bar{b}$
  - $gg \to H \to b\bar{b}$ difficult to see experimentally
  - Rely on primarily on associated production with W or Z
  - This talk
- High mass [m_H>135 GeV]:
  - Decays dominated by $H \to W^+W^-$
  - Easiest to look for leptonic decays of Ws
  - Considerable contribution from VBF and associated production
  - Marc's talk (next)



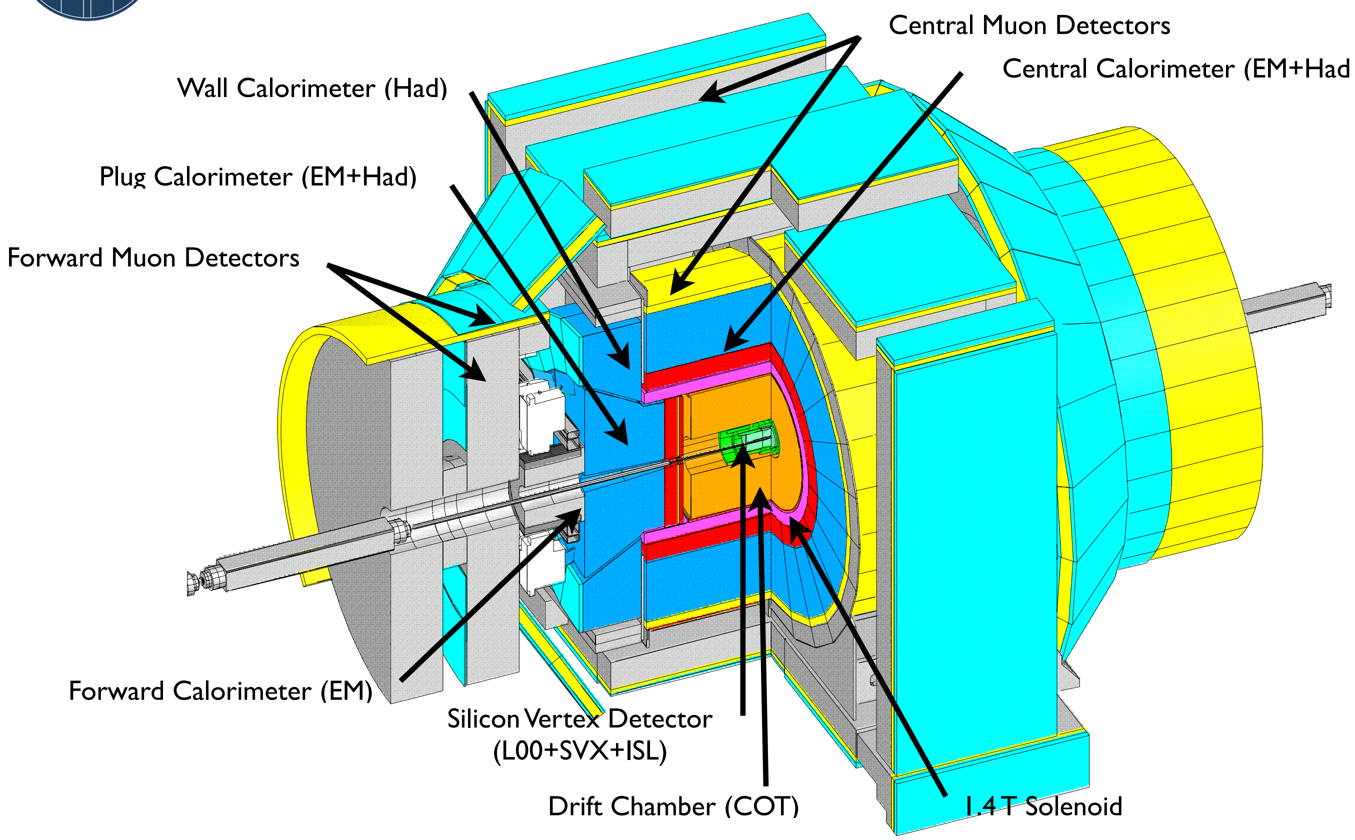


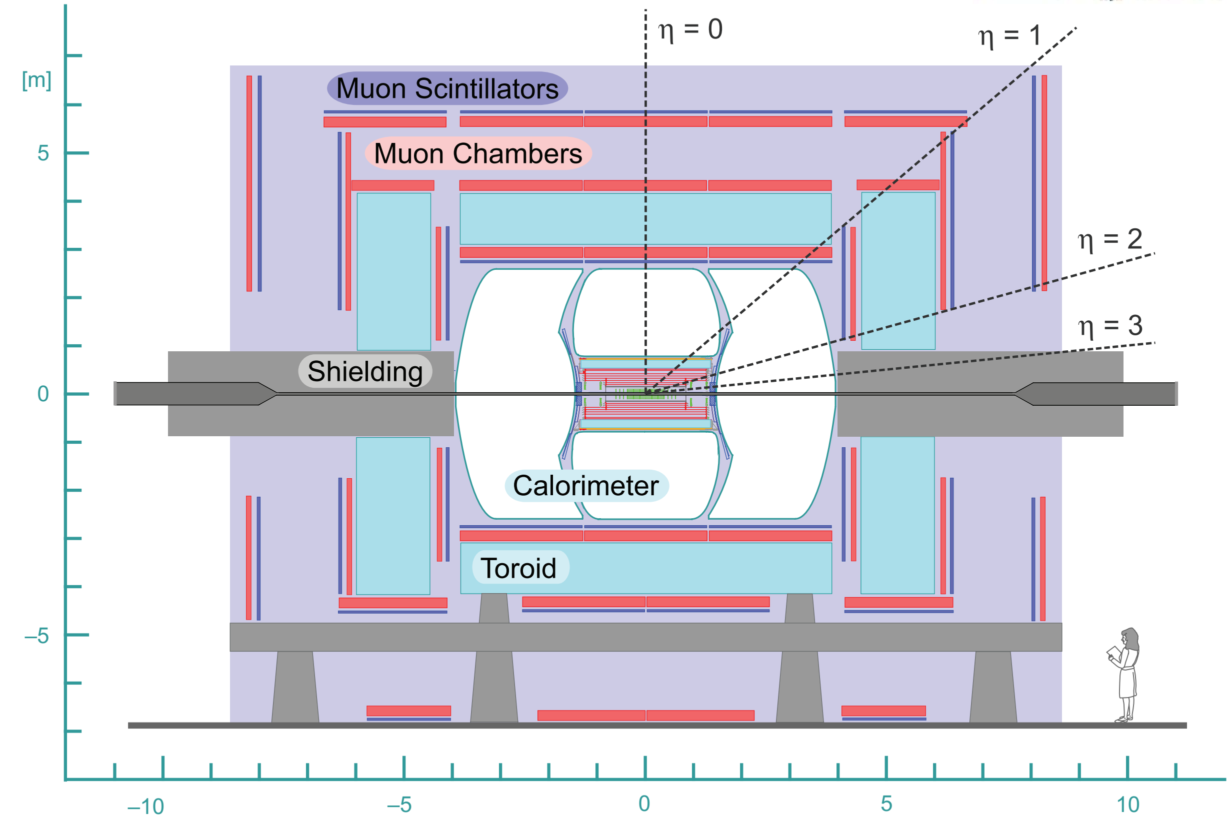
Experimental setup: Tevatron

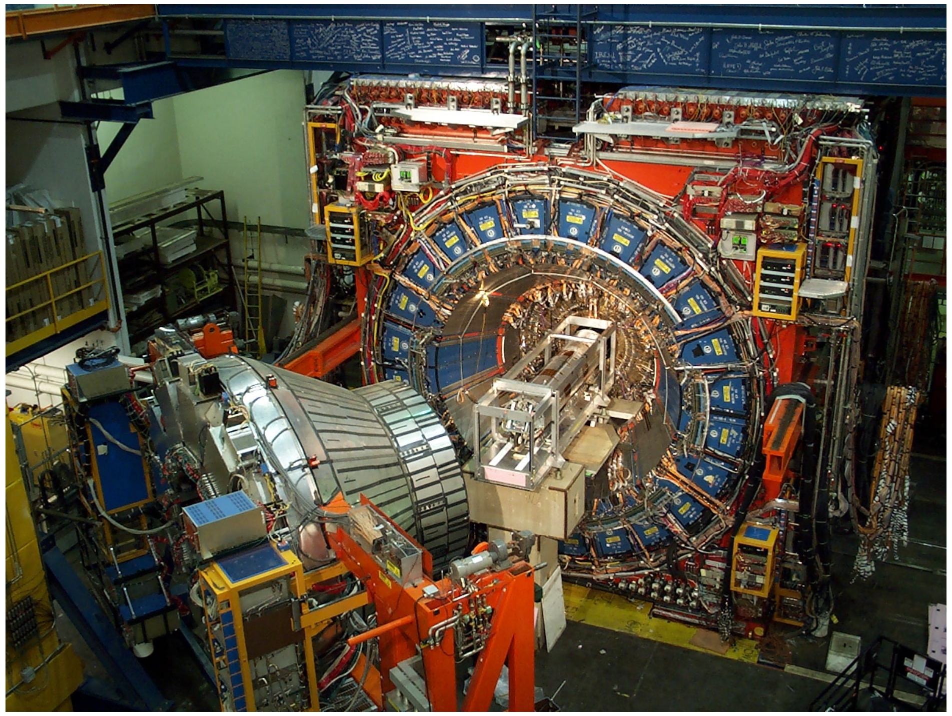
- 1.96 TeV ppbar collider
  - Highest energy p-pbar collider in the world
- Excellent accelerator performance
  - Quick startup after summer shutdown
  - Inst. lum. exceeding 3×10^{32} cm^{-2}s^{-1}
  - Over 7 fb^{-1} delivered to each experiment
  - Results shown today use ≲ 5.4 fb^{-1}
- Every bit of data helps
- Many thanks to the Fermilab accelerator division!



Experimental setup: CDF and DØ

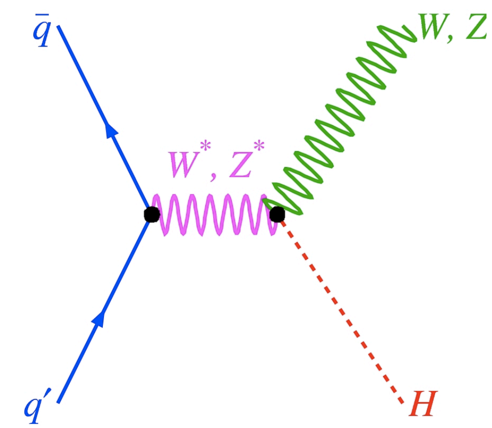




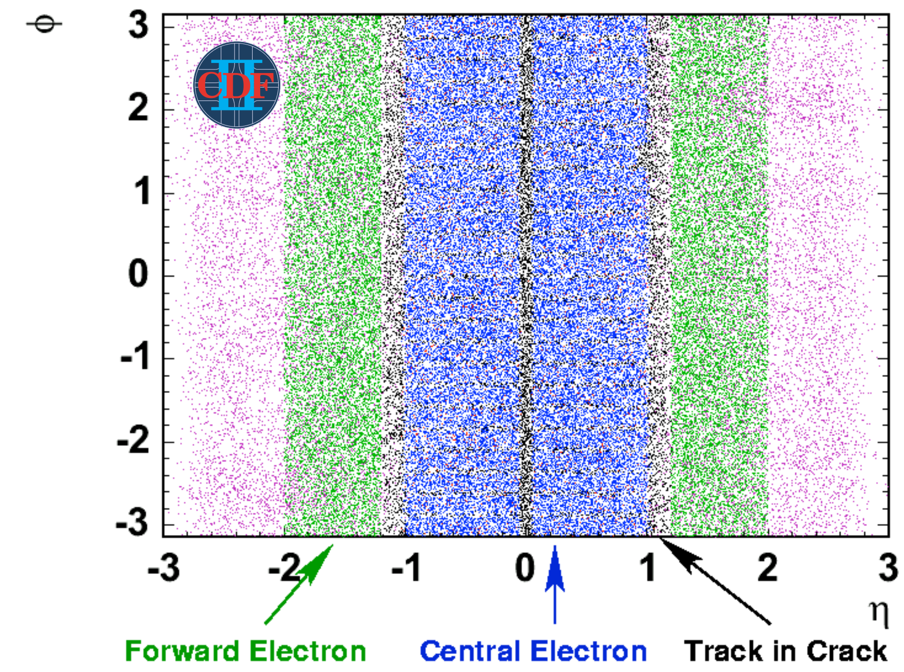


Low mass Higgs search strategy

- Identified leptons
  - *WH→lνbb̄, ZH→llbb̄*
- Invisible leptons
  - WH→(l)νbb̄, ZH→ννbb̄

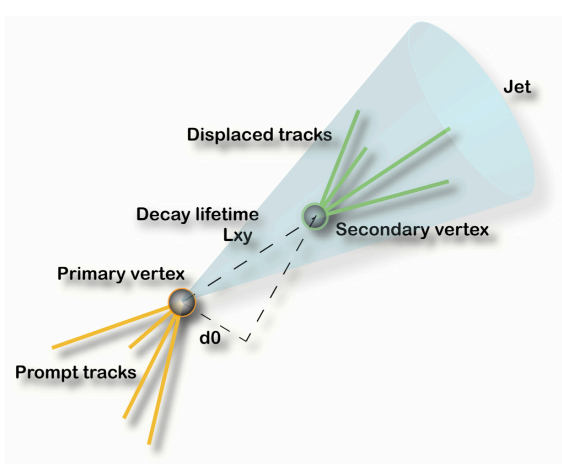


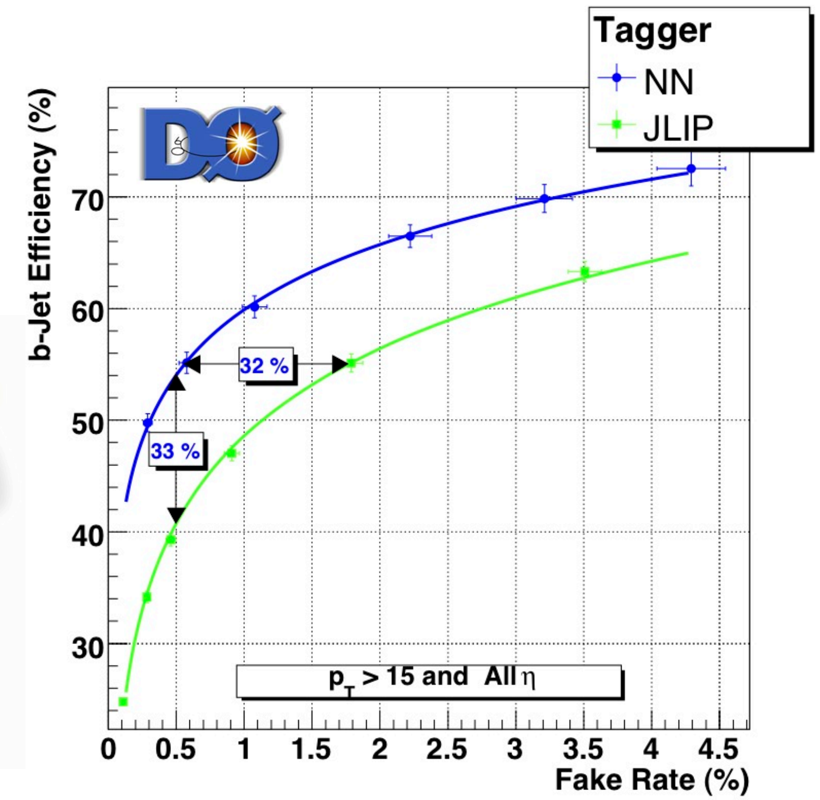
1. Identify *W/Z*: leptons (*e*,*μ*)
- Maximize lepton coverage
  - *e.g.* leptons not in fiducial region of calorimeter



2. Identify Higgs decay: jets
- Develop NN and other advanced tagging algorithms
- Develop multivariate jet corrections

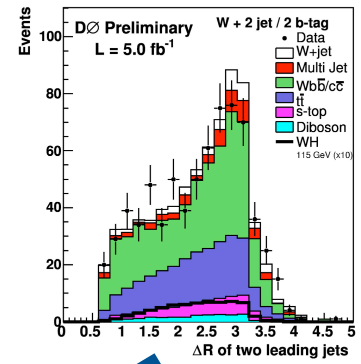
3. Reduce backgrounds
- Multijet backgrounds particularly difficult
  - Model using data
  - Use NN to separate

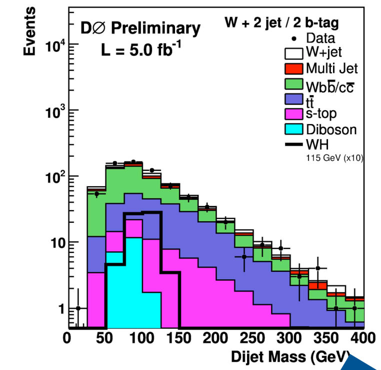


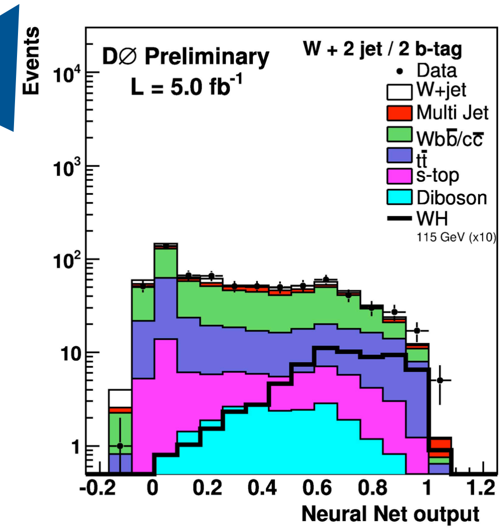


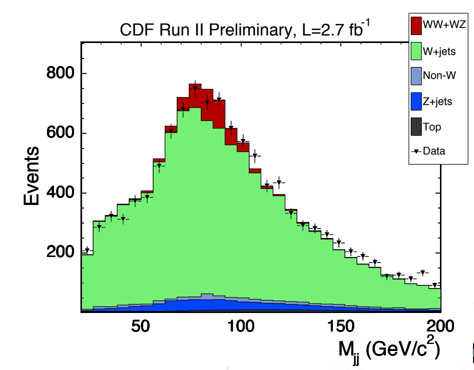
Signal extraction

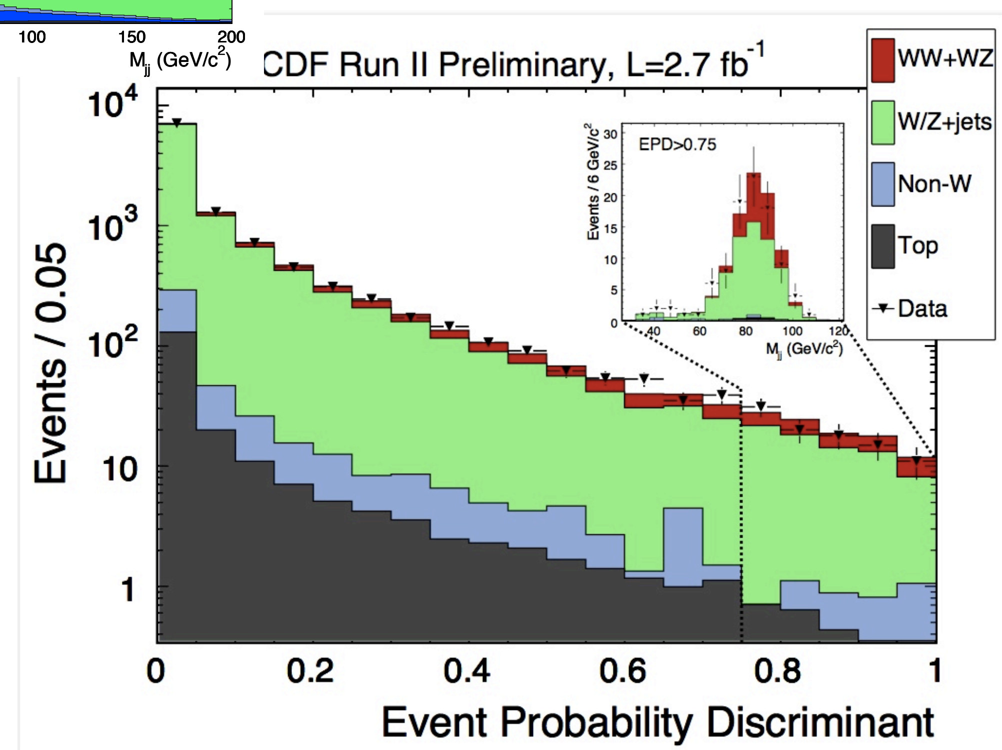
- Expected signals too small for counting experiments
- Don't want to rely on single kinematic distribution
- Exploit all possible information in an event: multivariate discriminants
    - Output single variable that looks at all event kinematics
    - Artificial Neural Networks (NN)
    - Boosted Decision Trees (BDT)
    - Matrix Element (ME) probabilities





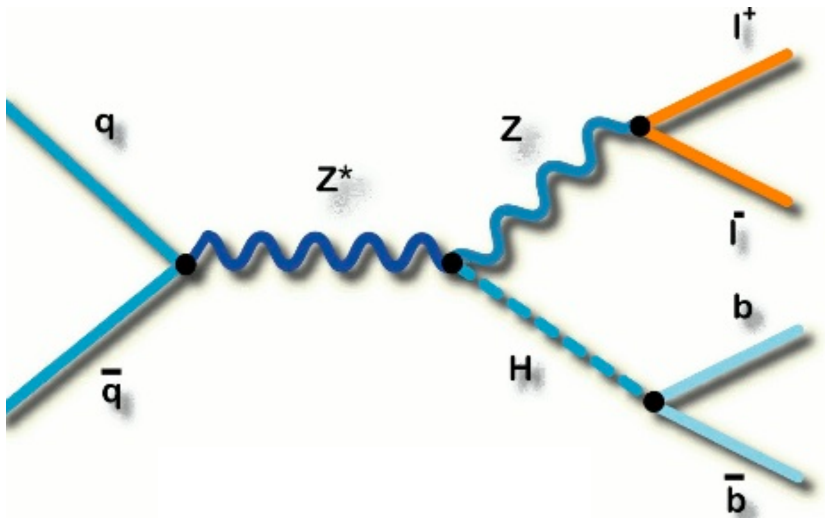




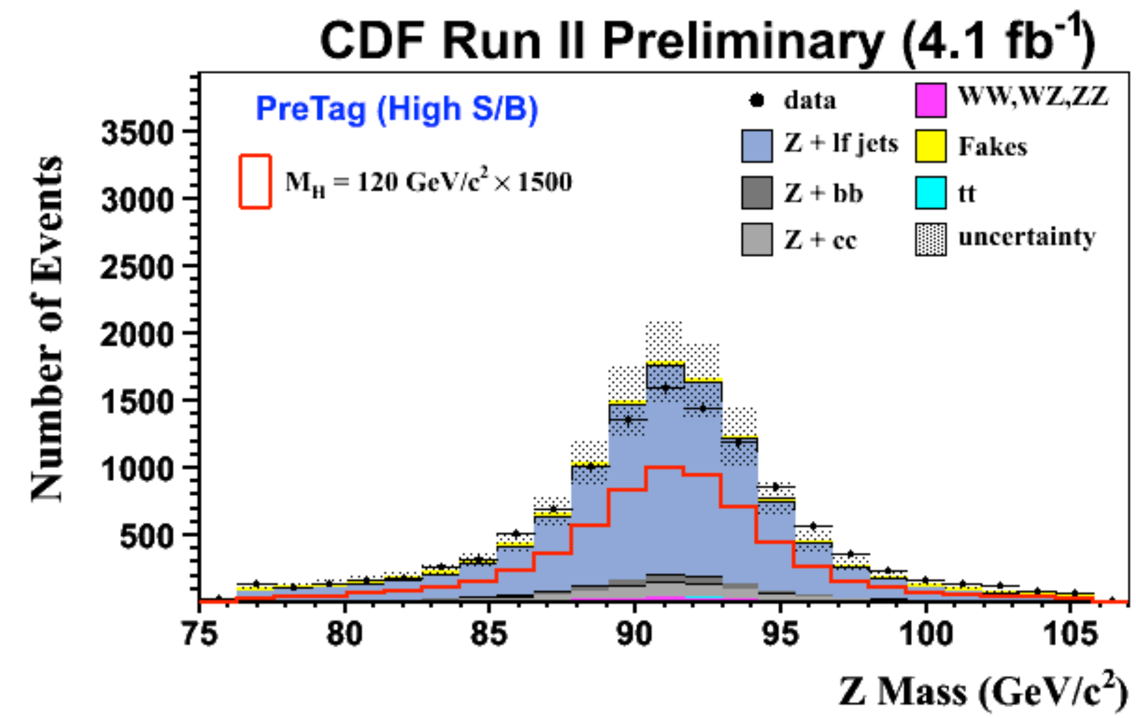


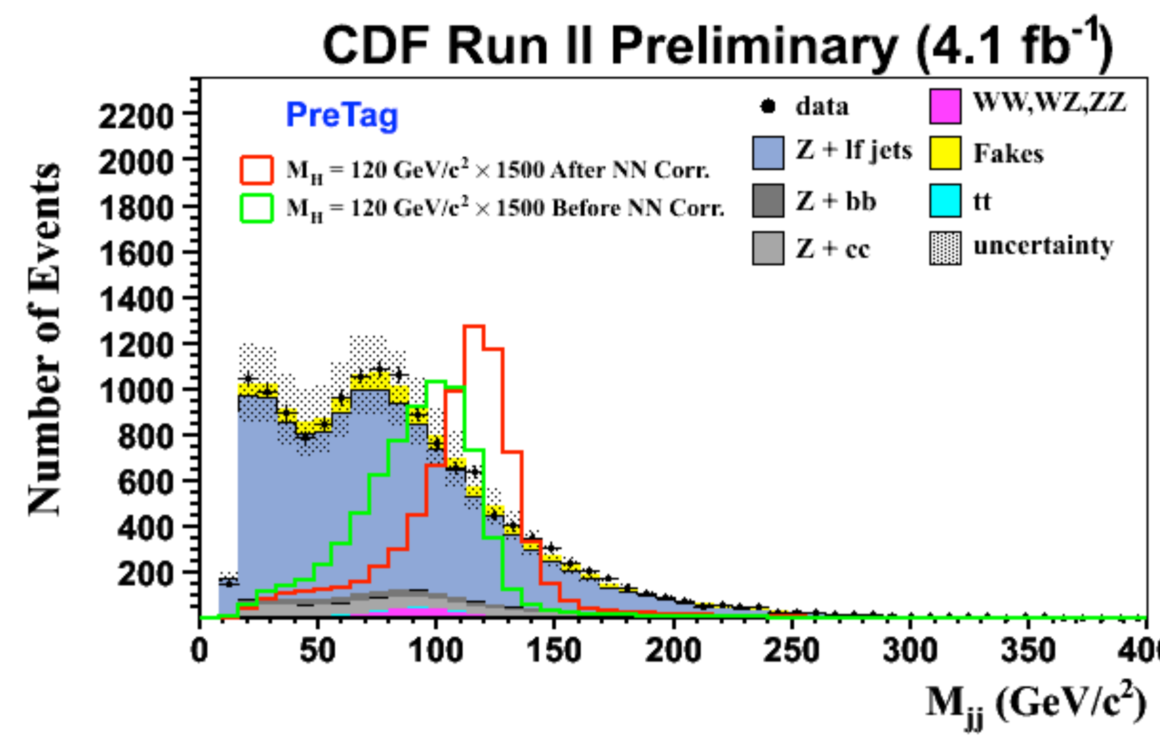
- Can we discover rare processes using these techniques? Yes
    - Single top
    - Hadronic decays of dibosons: very similar final states to low mass Higgs

$ZH \rightarrow llb\bar{b}$



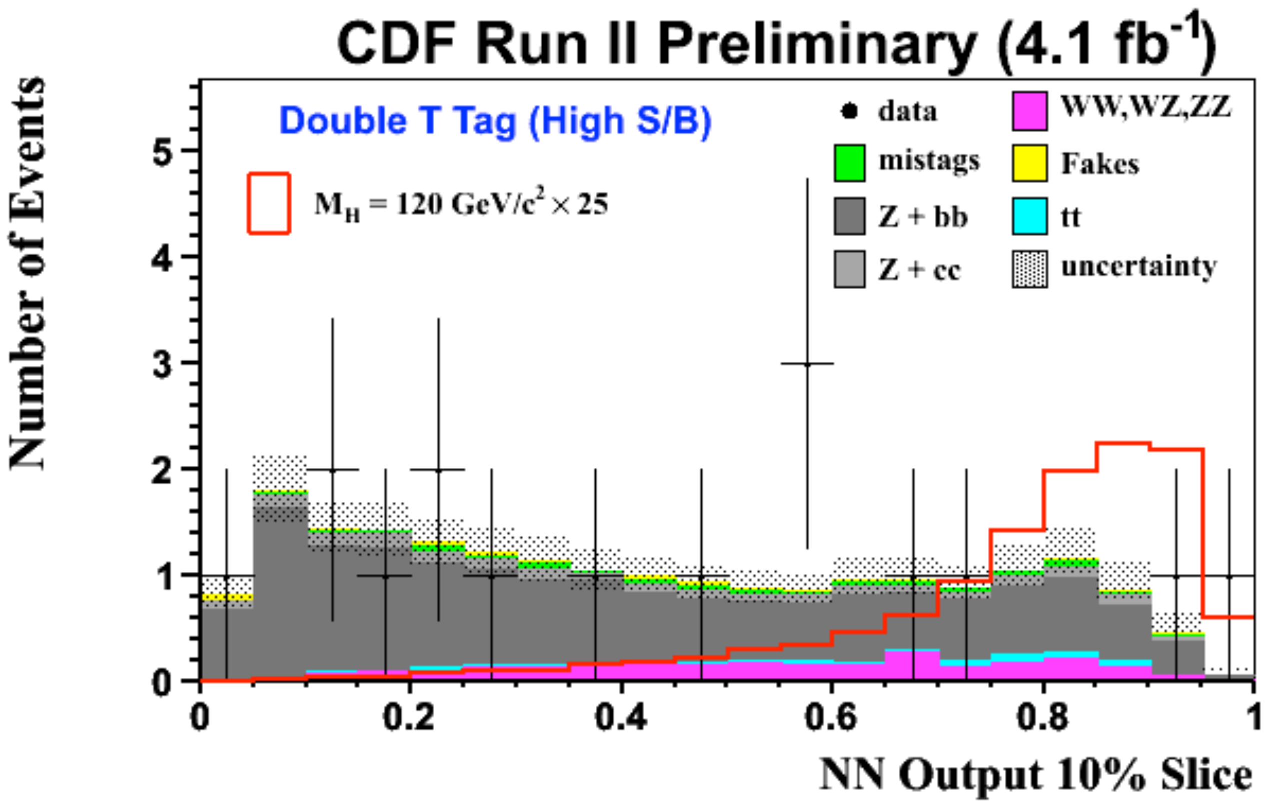
- Fully reconstructible final state
- Backgrounds primarily *Z*+jets, diboson and ttbar (little QCD)
- Very small signal rate

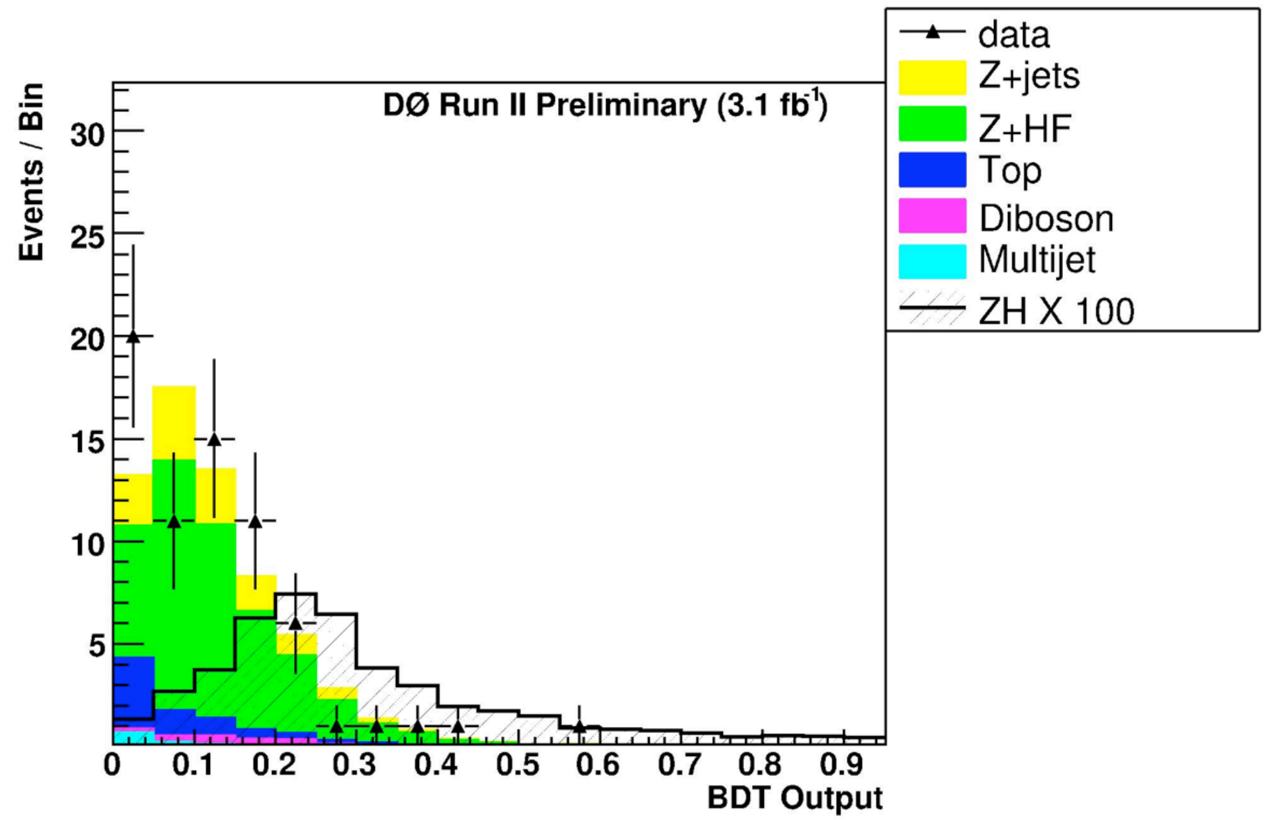




- Expand lepton selection to maximize acceptance
- Select events with 2 leptons, 2 jets, at least one of which is b-tagged
- Can use NN to improve dijet mass resolution

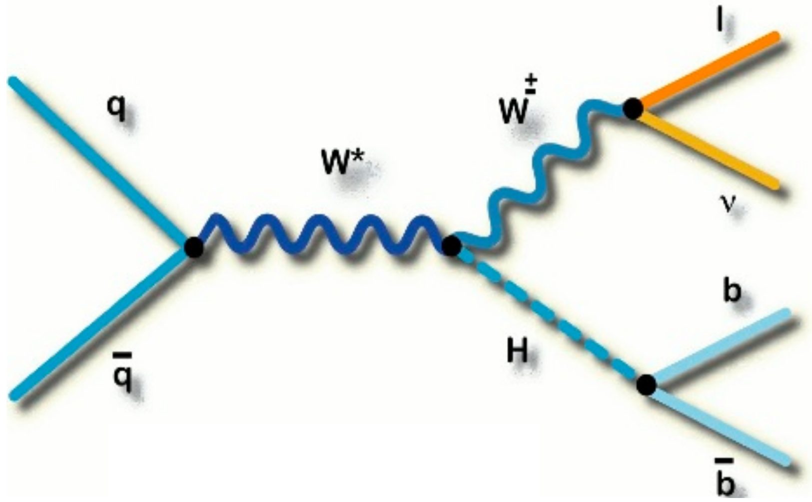
$ZH \rightarrow ll b\bar{b}$ results



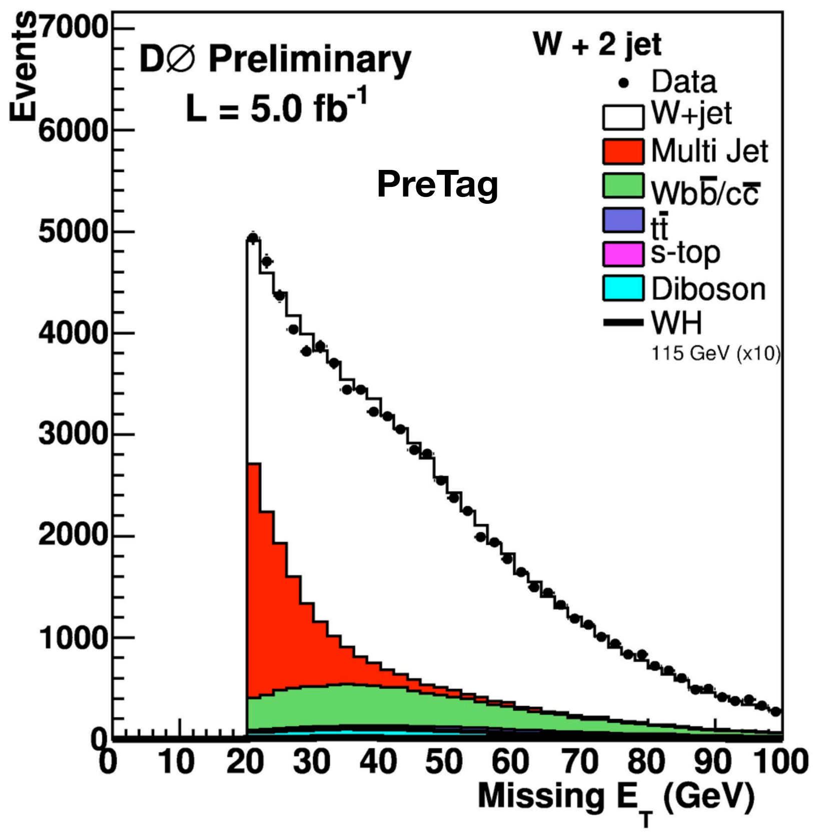


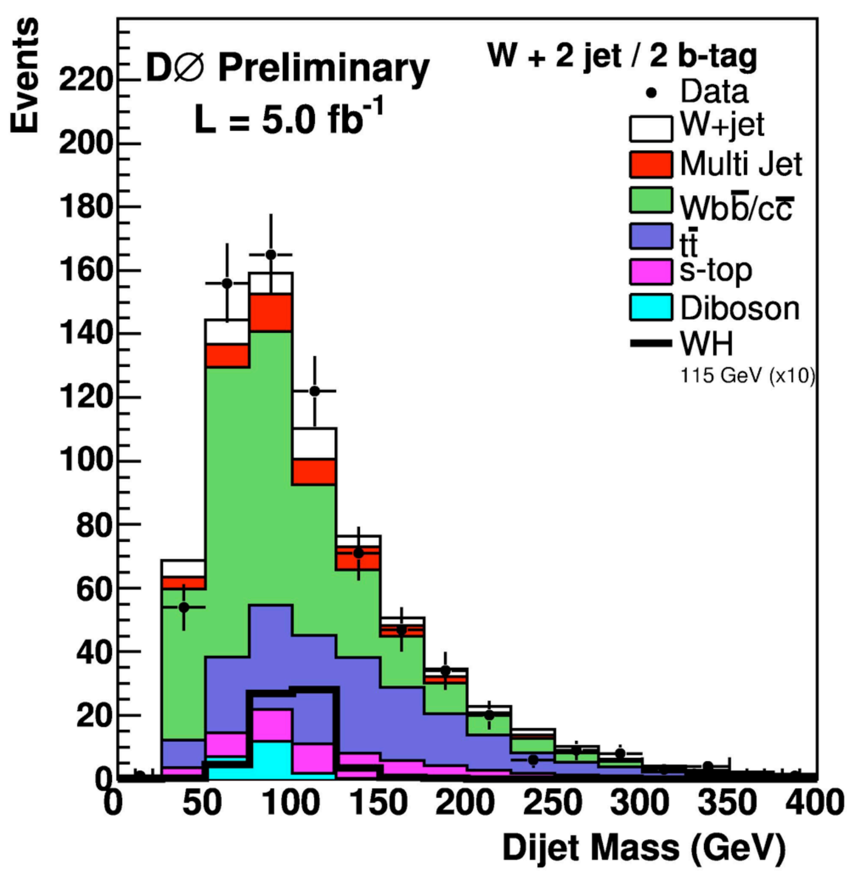
- CDF: 2D NN (ZH vs ttbar, ZH vs Z+jets), include leading order ME as input
  - 4.1 fb^{-1} Observe (expect) 5.9 (6.8)×σ_{SM} @95% CL for m_H=115 GeV
- DØ: boosted decision tree
  - 4.2 fb^{-1} Observe (expect) 9.1 (8.0)×σ_{SM} @95% CL for m_H=115 GeV

$WH \rightarrow l\nu b\bar{b}$

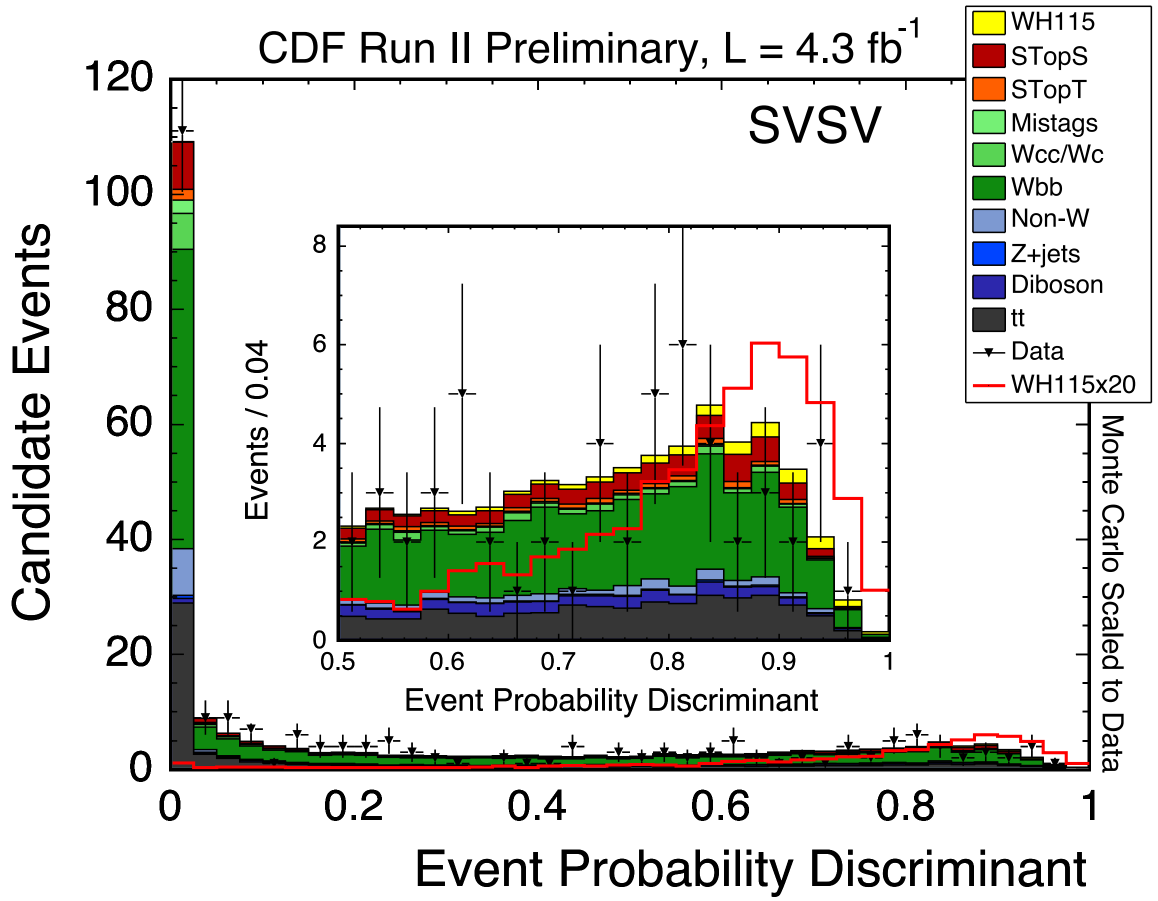


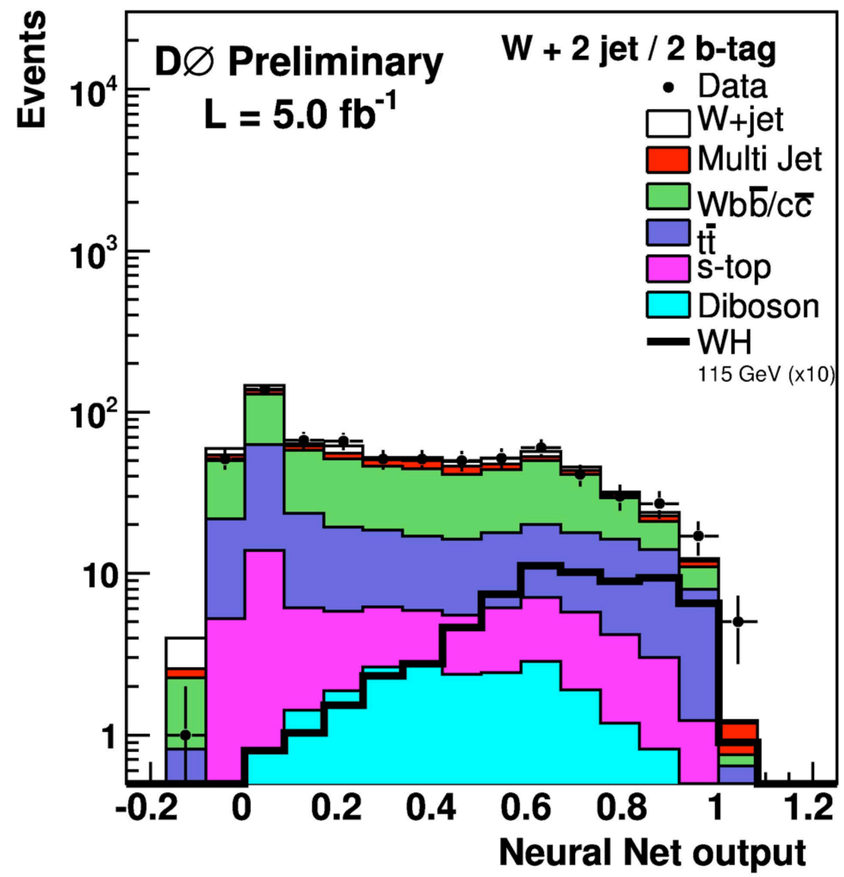
- Largest cross section of *VH* states with identified lepton
- Select events with high-p_T electron or muon, 2 or 3 jets at least one with a *b*-tag, and large missing E_T
- As with *ZH*, can use NN to improve dijet mass resolution
- Dominant backgrounds are W+jets, QCD multijet and top
- Split sample up according to number of jets and tags





$WH \to l\nu b\bar{b}$ results

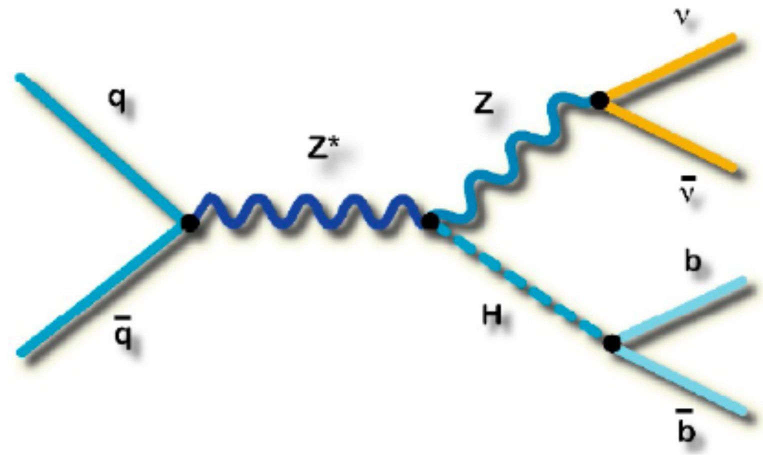


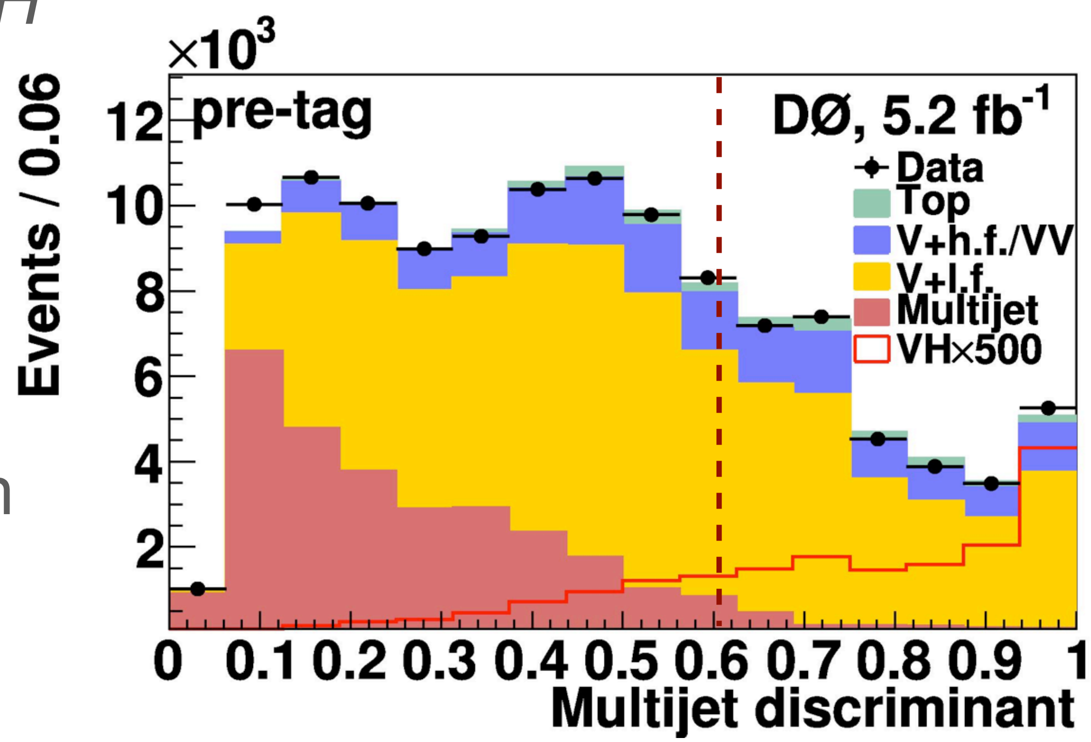


- CDF: ME (2 and 3-jet events)
  - 4.3 fb^{-1} Observe (expect) 6.6 (4.1)$\times\sigma_{SM}$ @95% CL for m_H=115 GeV
- CDF: NN (2-jet events)
  - 4.3 fb^{-1} Observe (expect) 5.3 (4.0)$\times\sigma_{SM}$ @95% CL for m_H=115 GeV
- DØ: NN (2 and 3-jet events)
  - 5.0 fb^{-1} Observe (expect) 6.9 (5.1)$\times\sigma_{SM}$ @95% CL for m_H=115 GeV

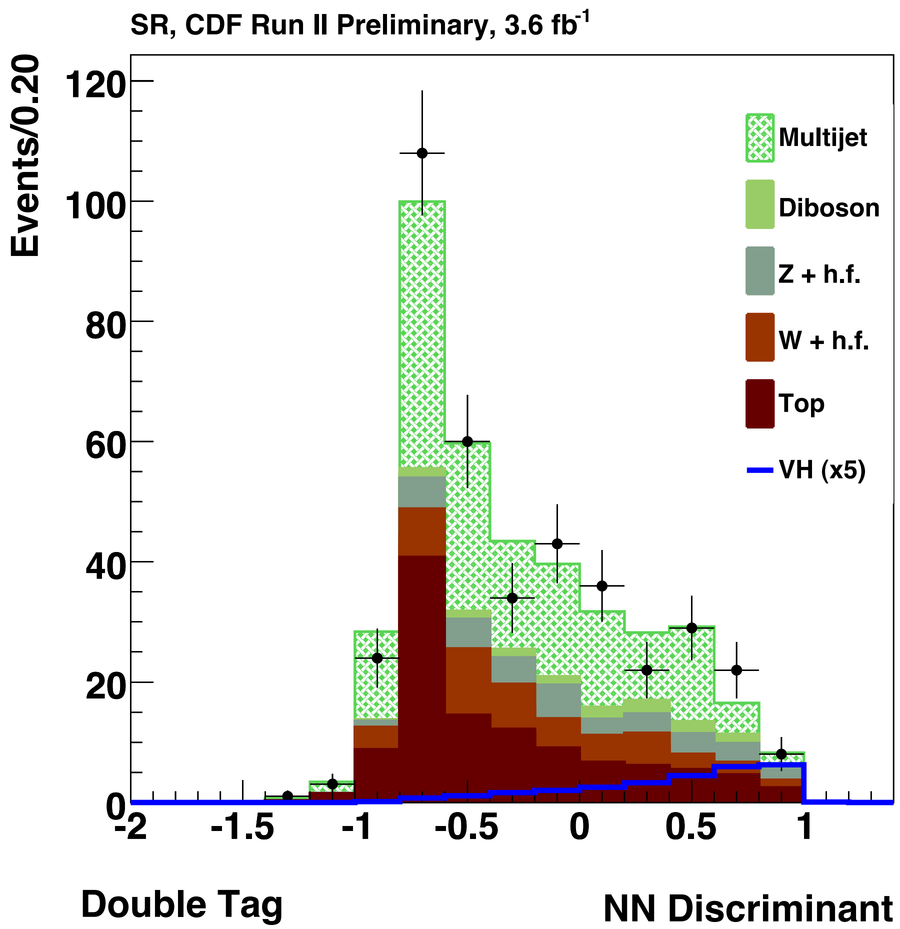
$VH \rightarrow b\bar{b} + \not{E}_T$

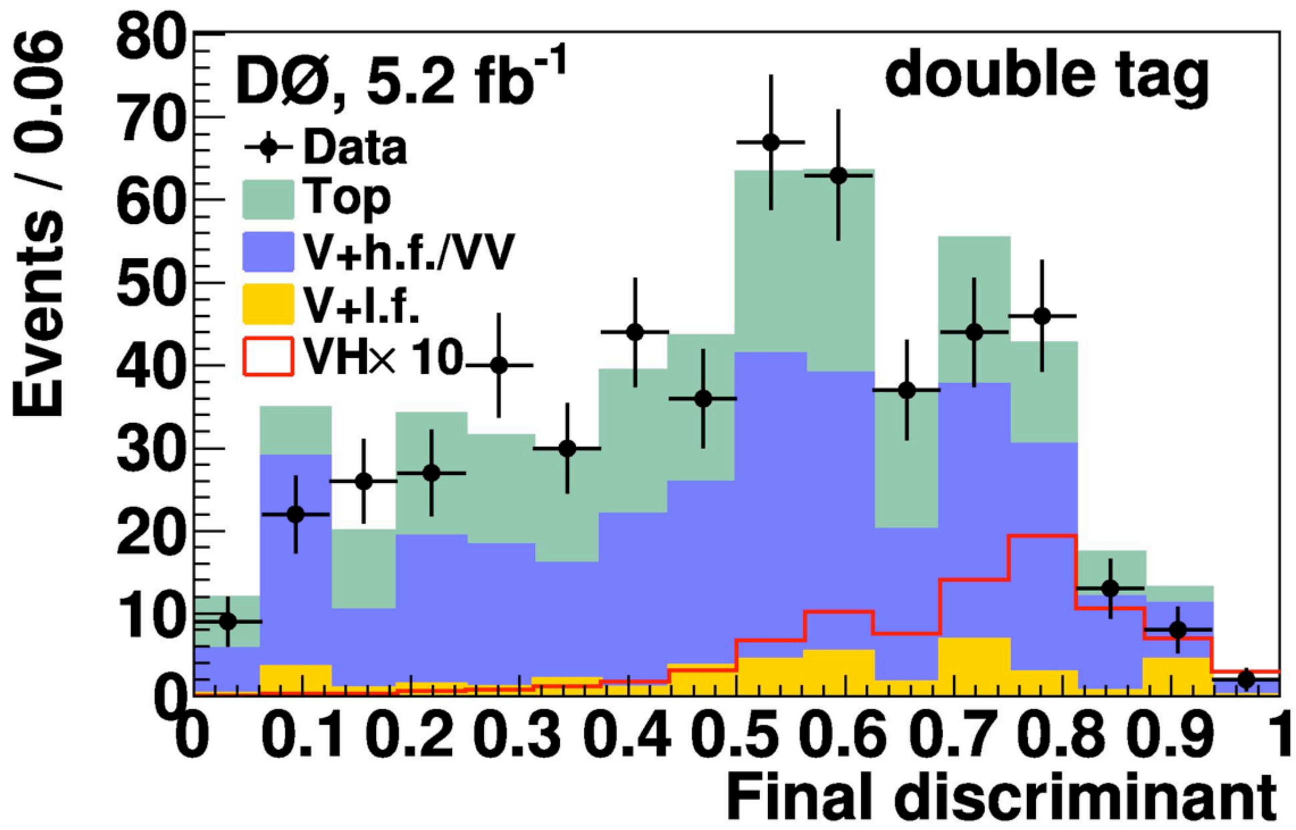
- Includes contributions from
  - $WH \rightarrow (l)\nu b\bar{b}$
  - $ZH \rightarrow \nu\nu b\bar{b}$
- Select events with large missing E_T and jets with at least 1 *b*-tag
- Exclude identified leptons
  - Ensures independent channel from other *VH* searches
- Backgrounds by source of missing E_T
  - Instrumental: QCD multijet
  - Real: W/Z+jets, top, diboson
- Large QCD background drives analysis design
  - Model using data
  - Use NN (CDF), BDT(DØ) to separate QCD background





$VH \rightarrow b\bar{b}+\not{E}_T$ results



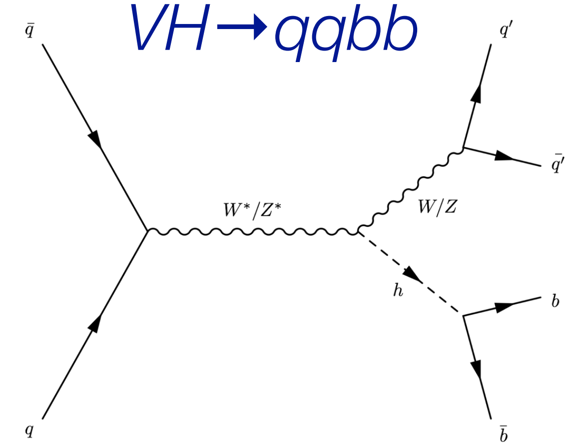


- CDF: neural net
  - 3.6 fb^{-1} Observe (expect) 6.1 (4.2)×σ_{SM} @95% CL for m_H=115 GeV
- DØ: boosted decision tree
  - 5.2 fb^{-1} Observe (expect) 3.7 (4.6)×σ_{SM} @95% CL for m_H=115 GeV

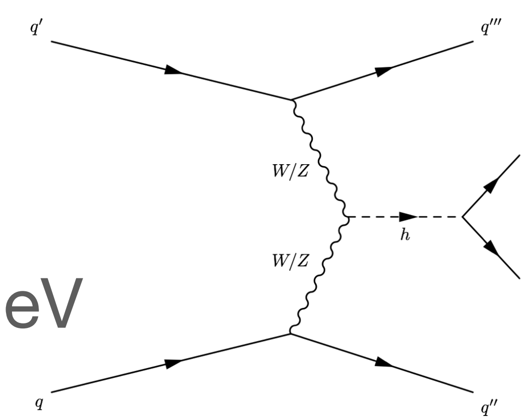
qqbb final state

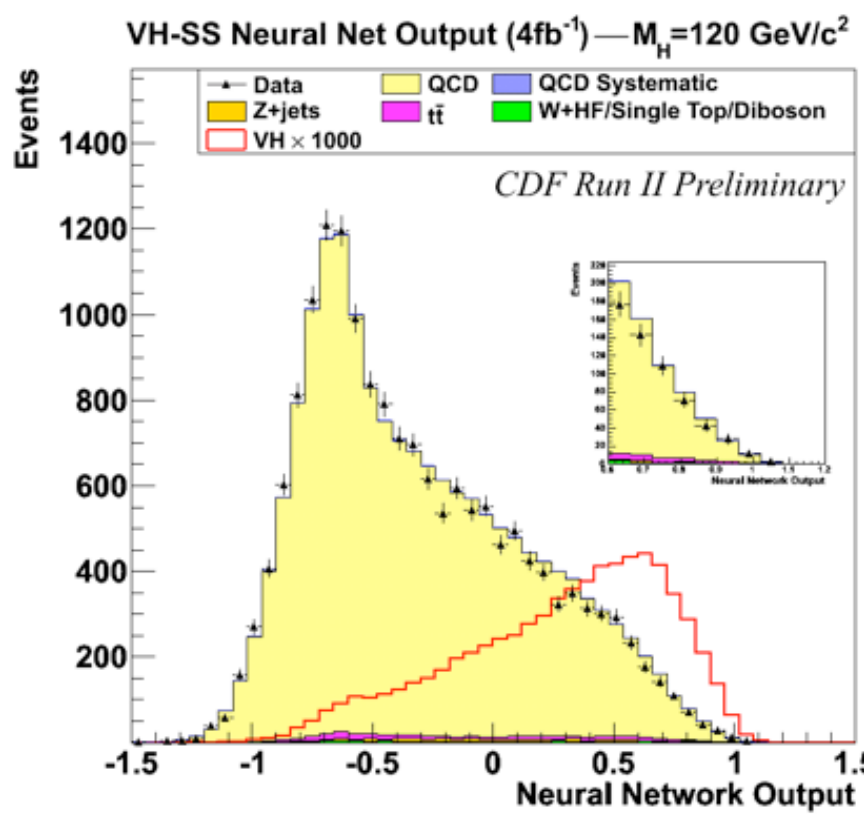
- Search for *VH→qqbb* as well as Vector Boson Fusion (VBF)
- Good
  - Has the largest signal yield of low mass searches
  - Fully reconstructable final state
- Ugly
  - Massive QCD multijet background
- Select events with ≥4 jets and 2 *b*-tags
- Use NN to separate QCD from Higgs
- 4 fb^{-1} Observe (expect) 10.4 (19.9)$\times\sigma_{SM}$ @95% CL for m_H=120 GeV

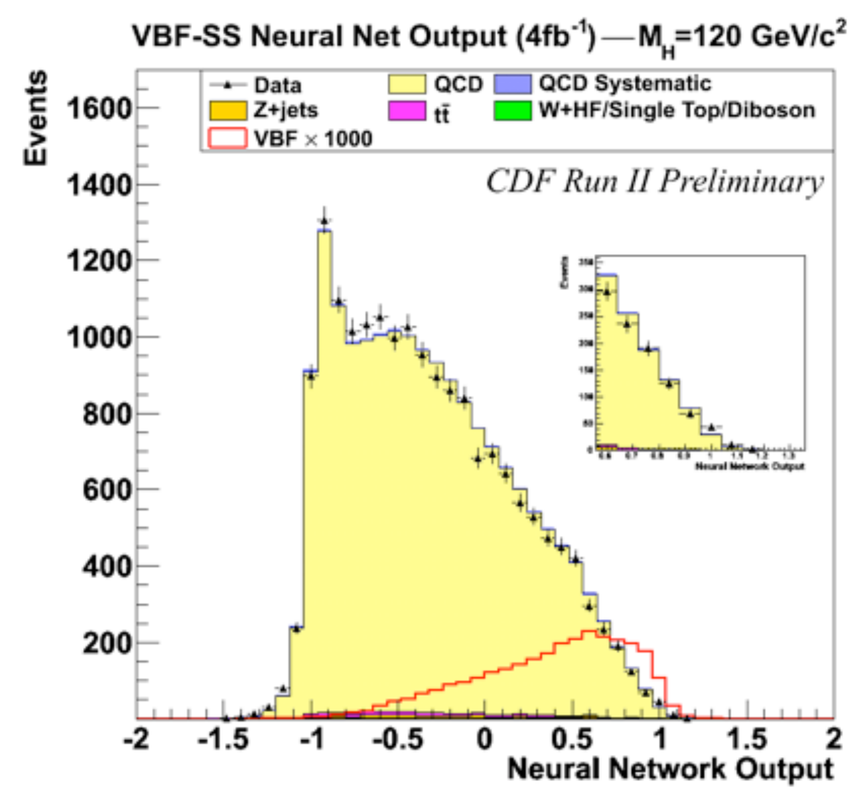
VH→qqbb



VBF

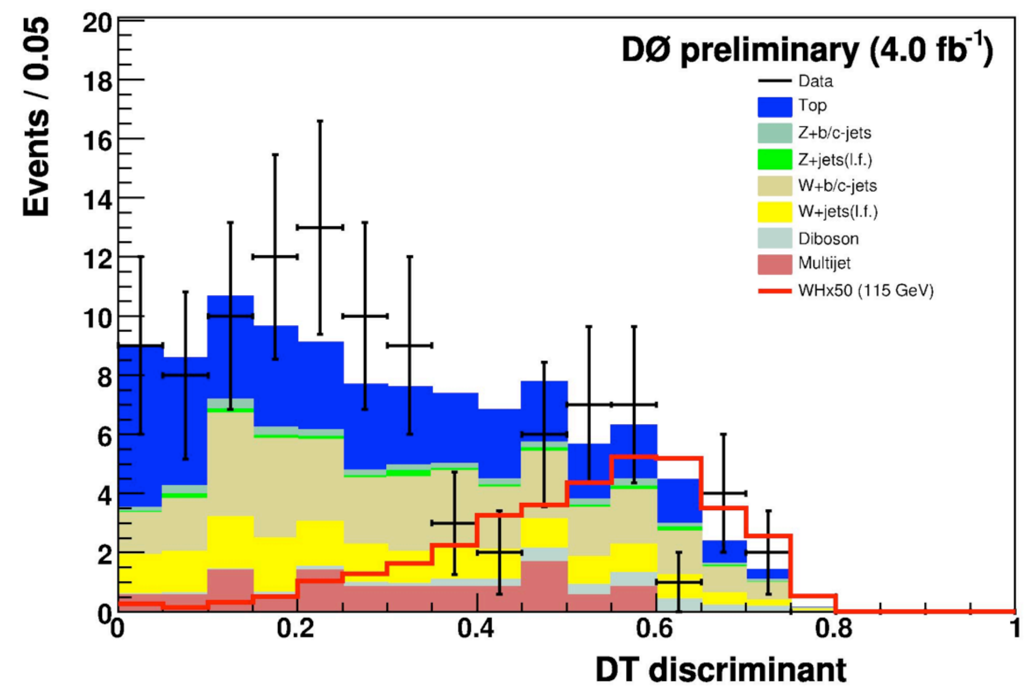


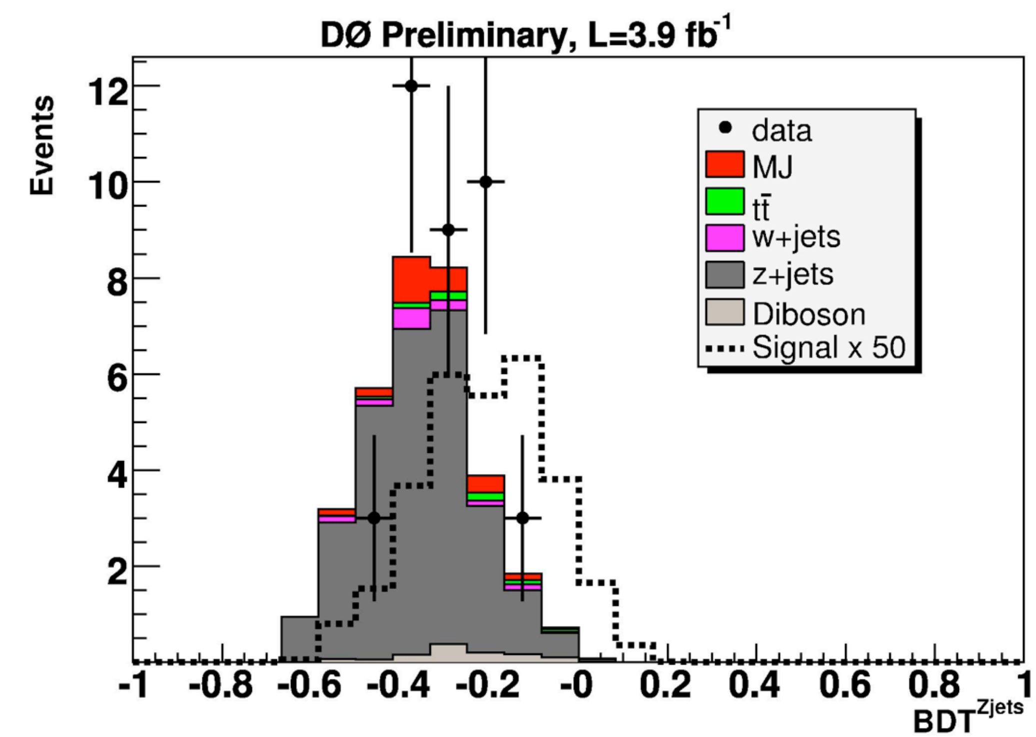




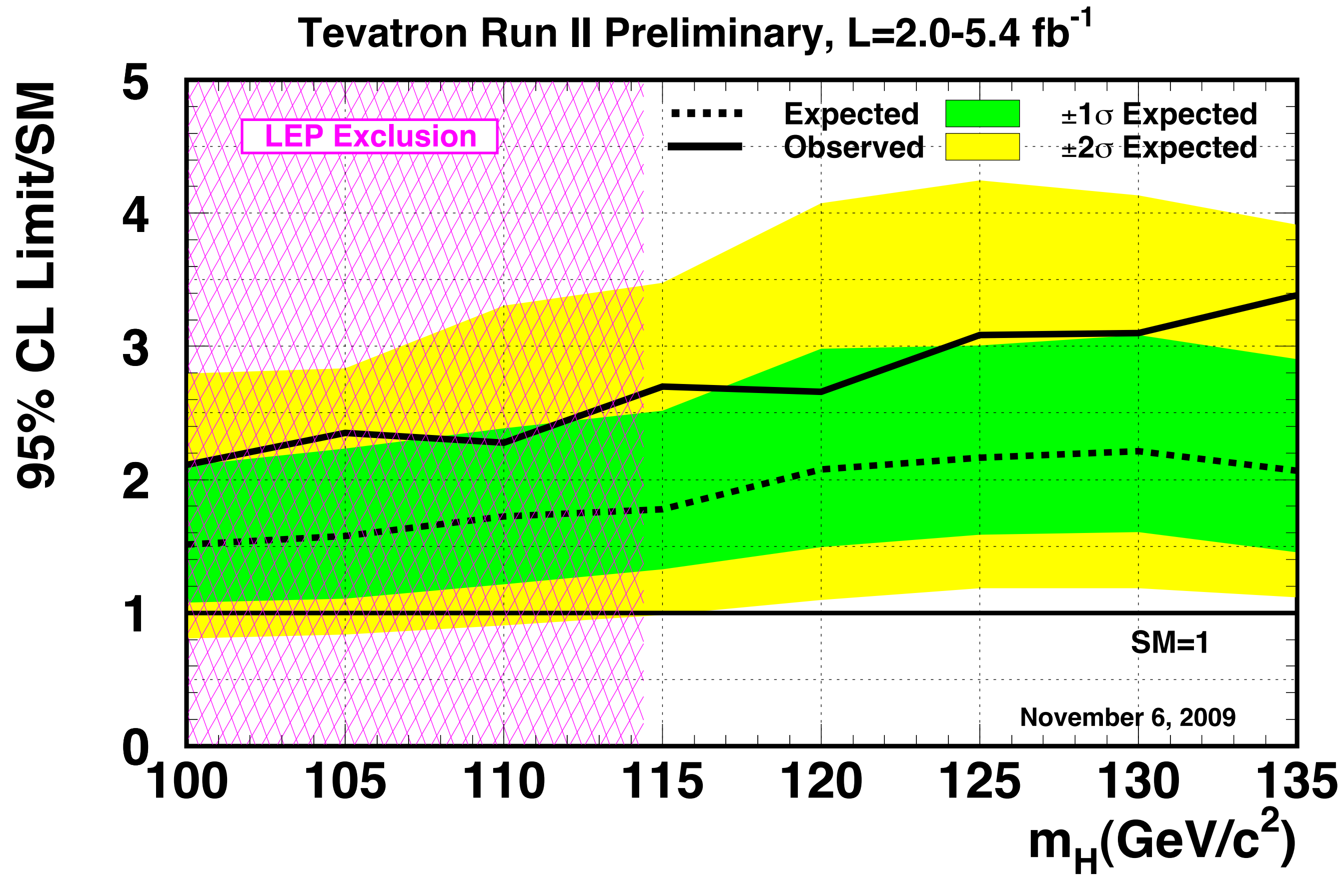
$WH \rightarrow \tau\nu bb$ and $\tau\tau qq$ final state

- $WH \rightarrow \tau\nu b\bar{b}$ complements $WH \rightarrow l\nu b\bar{b}$
  - Select events with 2 *b*-jets, missing E_T and hadronic τ
  - Use BDT as discriminant
  - 4.0 fb^{-1} Observe (expect) 14.1 (22.4)×σ_{SM} @95% CL for m_H=115 GeV
- Look for $\tau\tau qq$ to catch remaining tau final states
  - Includes events from $ZH \rightarrow \tau\tau b\bar{b}$, $HZ \rightarrow \tau\tau qq$, $HW \rightarrow \tau\tau qq$, VBF, and $gg \rightarrow H \rightarrow \tau\tau$+jets
  - Require one hadronic τ and one decaying to $\mu\nu_\mu\nu_\tau$
  - Use BDT as discriminant
  - 4.9 fb^{-1} Observe (expect) 27.0 (15.9)×σ_{SM} @95% CL for m_H=115 GeV





Conclusion



- Comprehensive search for low mass SM Higgs at CDF and DØ
  - Cover all associated production channels
  - High mass $H \rightarrow W^+W^-$ search also contributes at low mass
- Combined CDF+DØ sensitivity at m_H=115 GeV is now $1.78\times\sigma_{SM}$
  - Observed limit of $2.70\times\sigma_{SM}$ at m_H=115 GeV
  - See Marc's talk (next) for latest combination and future projections for Tevatron Higgs searches